RADIATION DAMAGE IN OPTICAL FIBERS AND ATTENUATION OF THE HF SIGNAL

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Radiation Damage in Optical Fibers and Attenuation of the HF Signal

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Abstract

The effects of radiation damage of optical fibers on the performance of the CMS very forward calorimeter (HF) were studied, using Monte-Carlo technique with the CMSIM software package. Based on the experimental data on optical fiber darkening due to radiation damage, and expected absorbed dose rate in the HF, we estimated attenuation of the signal in the HF towers. We estimated the uncertainty in the reconstructed energy because of different radiation damage corrections for hadronic and electromagnetic showers. The changes in the calorimeter response in process of CMS operation were also analyzed. It is shown that the HF response to the minimum bias (background) events may be used to monitor radiation damage of optical fibers and to calculate at least the first order correction accounting for it.

Measurements

Results of two experiments were combined for this analysis:

Snezhinsk, Russia

Co^{60} γ–source

0 – ~10 *Mrad* @ 10 *rad/sec*

0 – ~ 100 *Mrad* @ 80 *rad/sec*

CERN

500 MeV electron beam, samples embedded in iron

0 – 300 *Mrad* @ 600 *rad/sec*

(CMS Note 2001/020)

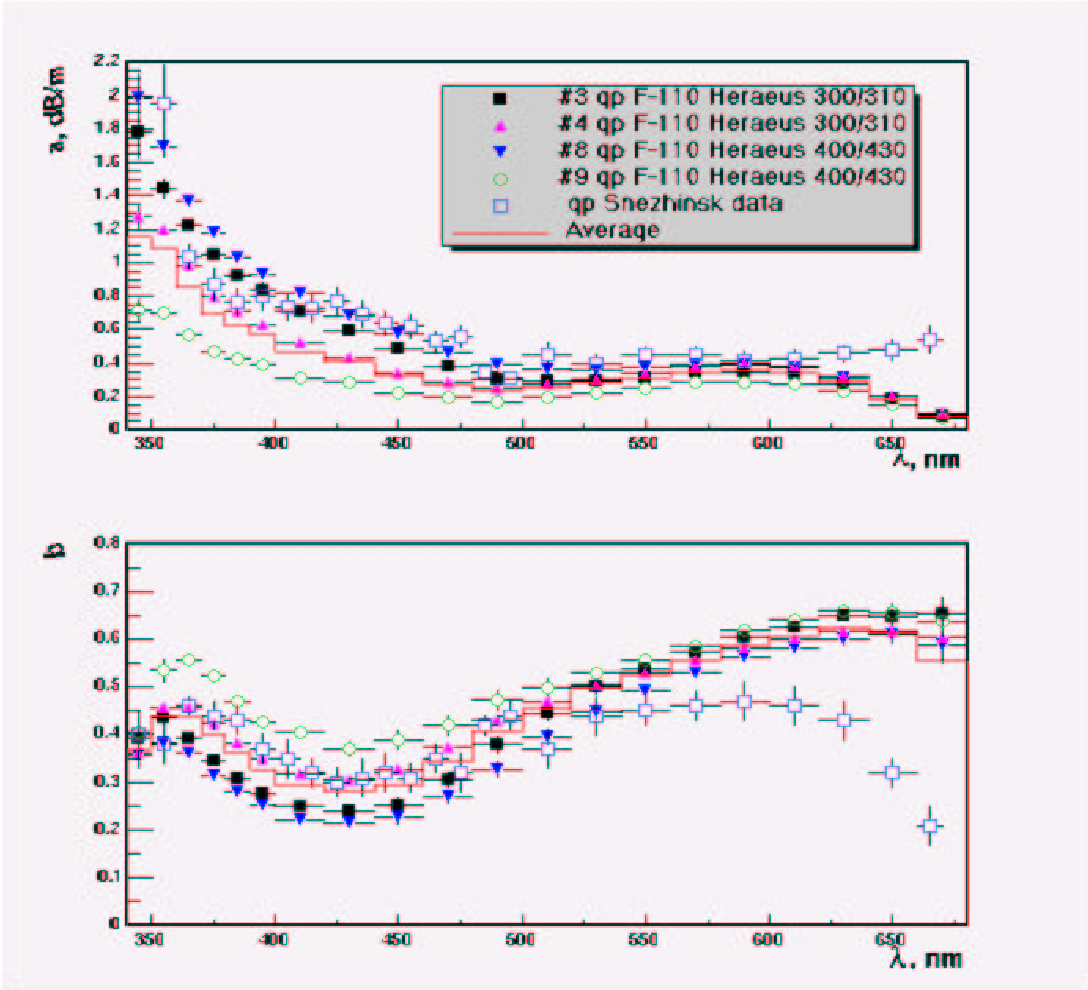
Data Representation

Data were combined as dose dependencies for each λ used in measurements, and then fitted to a power function .

$$A(\lambda)=a(\lambda)\cdot D^{b(\lambda)}$$

***A*–attenuation (in *dB/m*)**
***D*– Dose (in *Mrad*)**

- **Snezhinsk and CERN data are fully consistent for λ<550 *nm.***
- **Effect of disagreement outside this region is rather insignificant (because of the shape of the PMT quantum efficiency curve and Cerenkov light spectrum)**
- **For all practical purposes, a weighed average was calculated for all the data (histogram)**



Attenuation of the HF signal (η-dependence)

- 3K of Minimum Bias events − ~700K p.e.
- CMSIM125
- HF response with the shower library
- p.e.'s (their λ's, coordinates of production points) recorded in a data file.

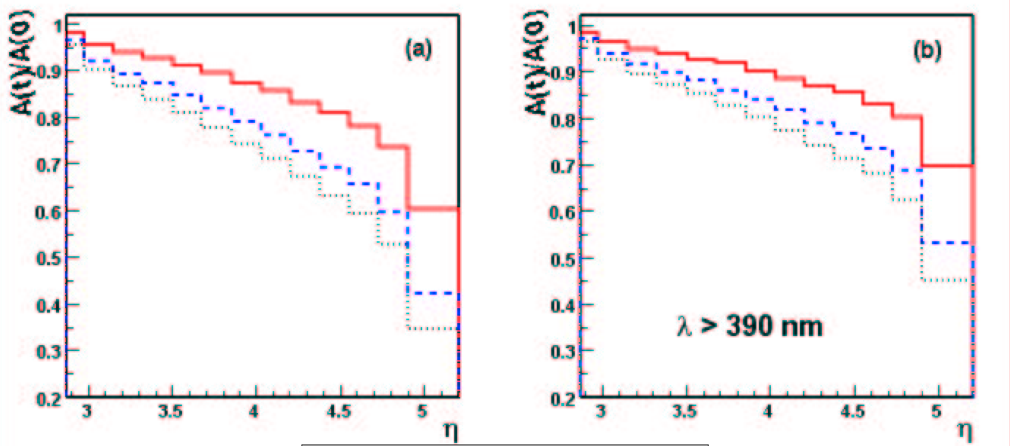
Probability for the photon to survive:

$$\exp\left(-\frac{\ln 10}{10}\int_{l_p}^{l_{max}} A(\lambda, D(z,r))\, dl\right)$$

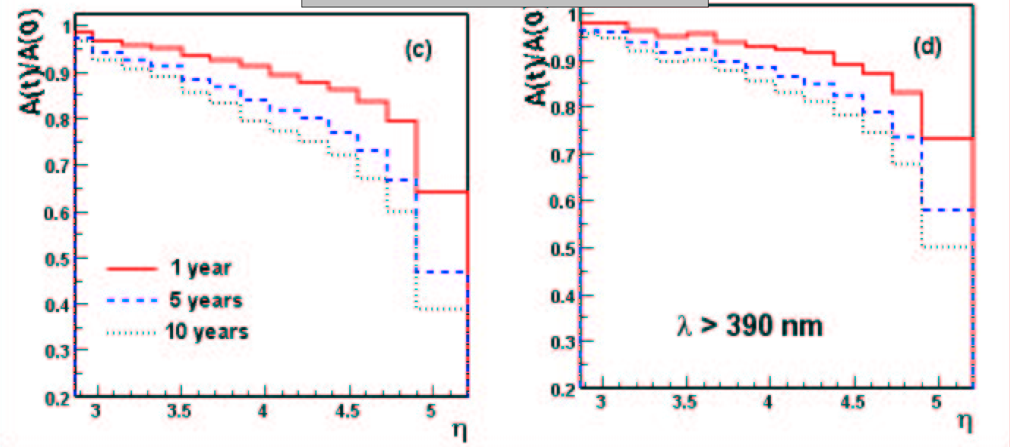
- **Attenuation parameterization (power function) with the dose map in the HF area, calculated for the TDR.**
- **Integration along the fiber path (including the gap between absorber and the PMTs).**

Up to 65% (55% with wave length filters) of signal is lost after 10 years of operation.

Long Fibers



Short Fibers



Attenuation of the HF signal within towers

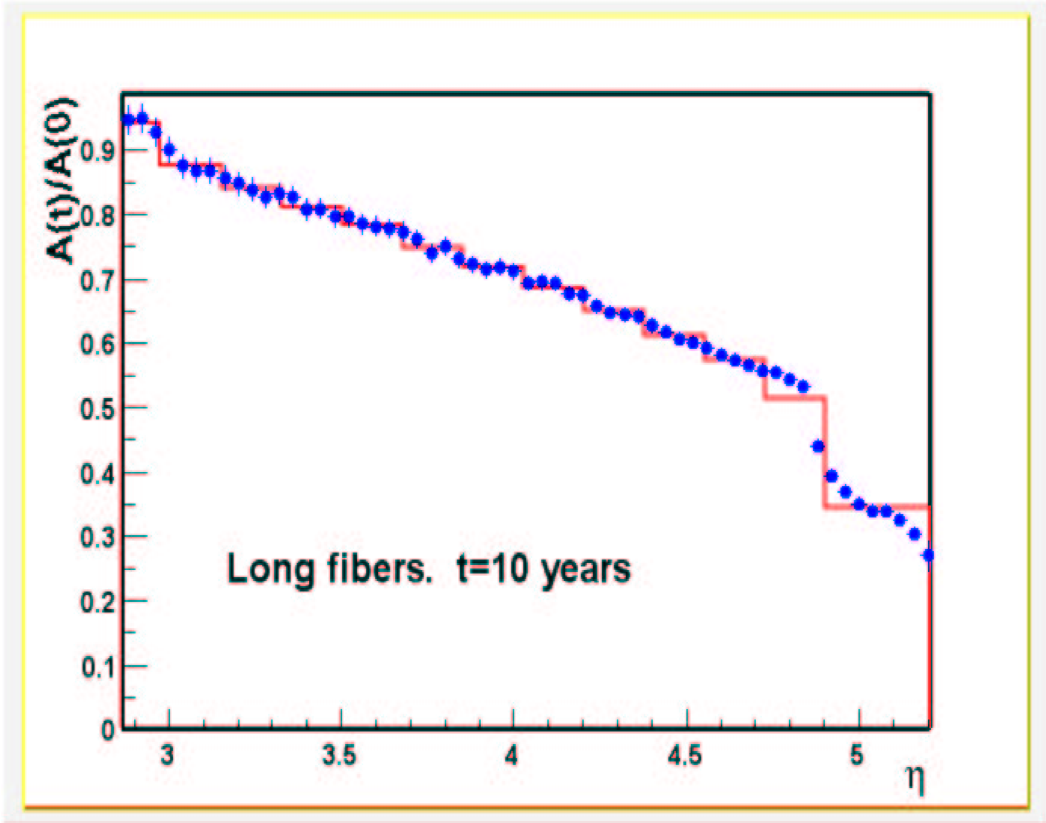
- Big difference in attenuation between towers (especially at high η)
- Steep changes in the absorbed dose with a distance from the beam.
- Beam pipe flange in front of HF, shadowing 2nd and 3rd towers

$\Downarrow$

Attenuation changes within the HF towers

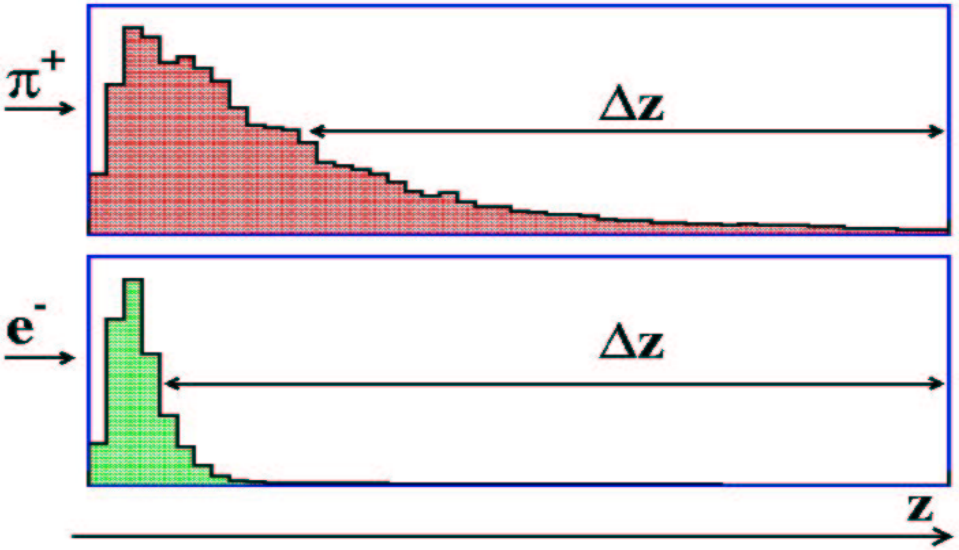
Within the first tower attenuation changes by a factor of ~2

Extra systematic shift in η calculated from the tower number.



Corrections for electromagnetic and hadronic showers

Electromagnetic and hadroic showers have different average depth ⇒ Cerenkov light from intial hadrons and e/γ travels different distance to PMT, being affected differently by radiation damage of optical fibers.



This introduces an extra uncertainty in the reconstructed energy of the jet/energy flow of unknown (model dependent) composition

Radiation damage correction at the time *t*

$$c=\frac{A(t)}{A(0)}$$

Two "extreme" cases − initial hadrons and e/γ (corresponding corrections and energies are c_h, c_e and E_h, E_e. Then,

$$\frac{\Delta E}{E}\equiv\frac{E_e-E_h}{(E_e+E_h)/2}=2\cdot\frac{c_h-c_e}{(c_h+c_e)}$$ will be upper estimation of this uncertainty

Corrections for electromagnetic and hadronic showers(continued)

CMSIM allows separation of the HF response based on the type of incoming particle.

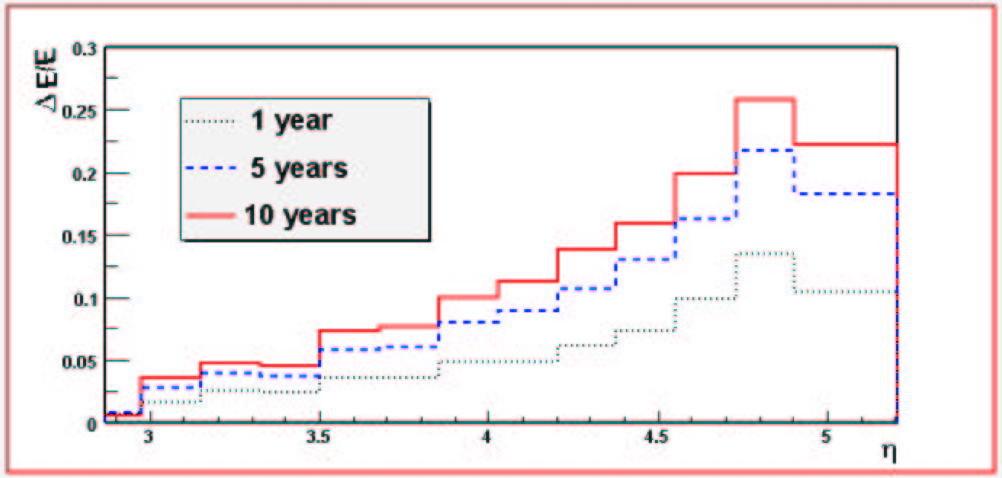
For towers > #3 (η<4.552), this uncertainty does not exceed 15% for all the time of the HF operation.

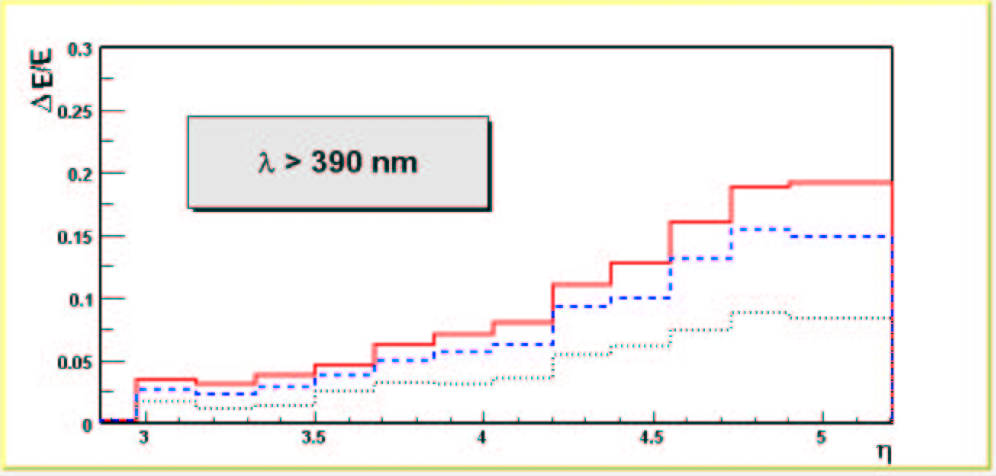
In real life − background event, i.e. mixture of hadrons and electrons $\Rightarrow$

$$c_{mb} = A_{mb}(t)/A_{mb}(0)$$

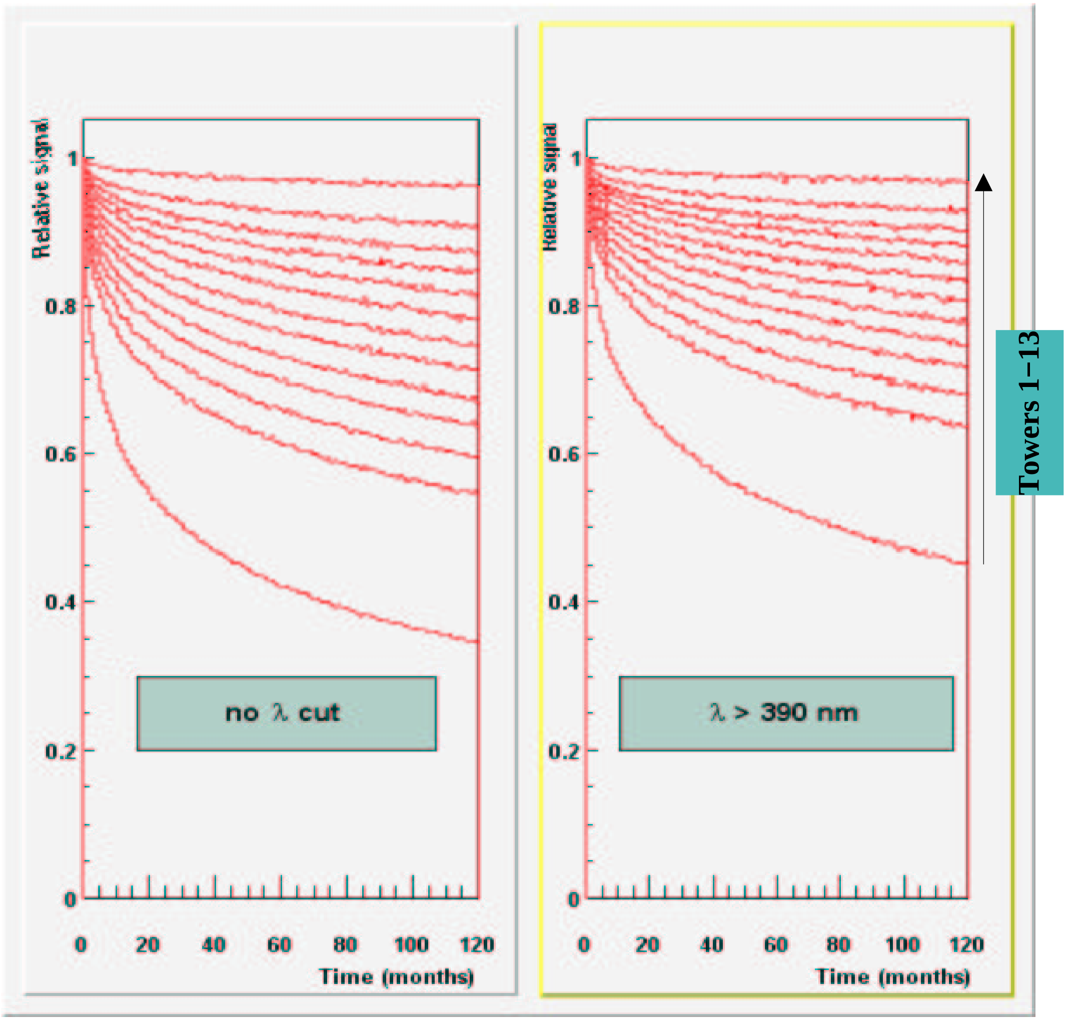
introduces even smaller uncertainty

MB events can be used to calculate at least as a first order radiation damage correction.



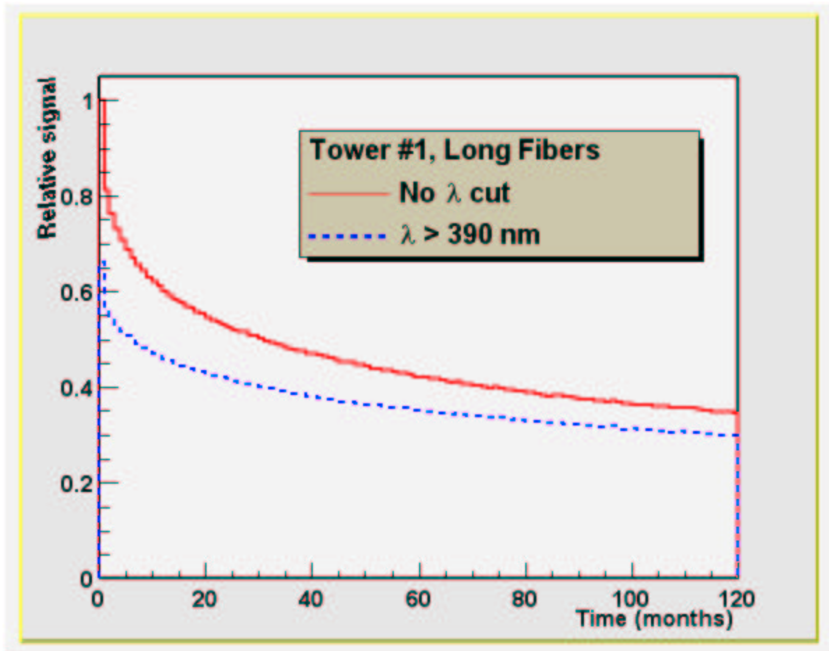


HF Signal vs Time of Operation



Tower #1 loses ~20% of its signal during the 1st month of operation.

Wavelength filter (λ>390 nm) improves stability, but kills ~20% of the signal .



Conclusions

- The HF will lose up to 65% (55% with the wavelength filters) of its signal after 10 years of operation.
- The minimum bias events can be used for monitoring of the HF performance and for calculation of the radiation damage corrections (at least of the first order corrections)
- Close monitoring/recalibration is most needed at the beginning of operation, when the HF signal changes faster.
- The wavelength filters improve stability of the HF signal but decrease its absolute value by ~20% (under assuption of the same reflectivity of mylar and 3M material)

UNCERTAINTIES

- ✔ **The conclusions heavily depend on the results of irradiation measurements with $\gamma-$ source. Radiation damage from hadrons can be different.**
- ✔ **Higher radiation damage rate from hadrons can increase the difference between corrections for electrons and pions, as well as the dynamics of the behaviour of the HF signal with the time of operation.**